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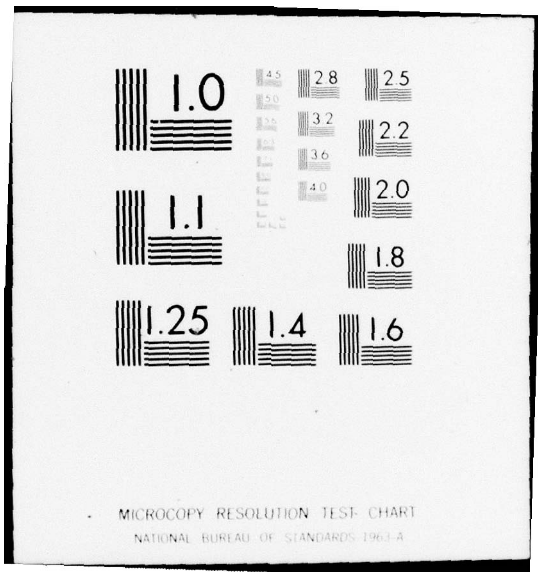
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14 Flow Research Communication ~~No.~~ 75

9 Final Report For ONR Contract 1 Jul 74-30 Jun 75

15 No. N00014-72-C-0355

6 Numerical Turbulence.

By

10 Steven A. Orszag

11 July 1977

12 10p.

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Flow Research Communication No. 75
July 1977

This communication summarizes the work performed on ONR Contract No. N00014-72-C-0355, Task NR 061-223, "Numerical Turbulence." Significant results have been reported in the reports referenced in this paper.

Contract Number: N00014-72-0355
Program Code Number: NR 061-223
Name of Contractor: Flow Research Company, A Division of Flow Industries, Inc.
Effective Date of Contract: 1 July 1974
Contract Expiration Date: 30 June 1975
Amount of Contract: $40,000
Principal Investigator and Phone Number: Dr. Earll Murman (206) 854-1370
Scientific Officer: Ralph C. Cooper
Short Title of Work:

In "Pseudospectral Approximation to Two-Dimensional Turbulence," Fox and Orszag (1973) introduced the pseudospectral technique for the calculation of fluid flows. This technique is now very widely used by many research groups throughout the world for numerical simulation of turbulent flows, atmospheric pollution problems, etc. The technique combines efficiency with accuracy and is ideal for many problems.

In an unpublished report, Metcalfe and Orszag (1973) developed spectral methods for the solution of the linear stability problem for pipe flows. It was demonstrated that pipe Poiseuille flow is stable to both axisymmetric and non-axisymmetric disturbances. It was also shown that a small rotation of the pipe flow is destabilizing. The techniques developed in this work have found application in the development of fast and accurate computer codes for the solution of general fluid flow stability problems. A paper (written jointly with M. Deville) summarizing these results and other applications (for example, to non-axisymmetric disturbances of Couette flows between rotating cylinders) is being prepared for publication.

In "Numerical Simulation of the Turbulent Wake of a Self-Propelled Body," Orszag and Pao (1973) summarized the results of pseudospectral calculations of the flow in the turbulent wake of a self-propelled body. These calculations represent the first calculations of turbulent shear flows using the Navier-Stokes equations with no modelling approximations.

In "Minicomputers vs. Supercomputers: A Study in Cost Effectiveness for Large Numerical Simulation Programs," Orszag (1973) investigated the possibility that minicomputers could compete effectively with super computers on large hydrodynamics computer codes. This subject has since become more fashionable, with several research groups continuing the investigation.

In "Numerical Computation of Turbulent Shear Flows," Orszag and Pao (1974) reported results of direct numerical simulations of wake flows. The results, while crude because of the limited spatial resolution of available computers, indicated the great possibilities for direct numerical simulation of turbulent shear flows, as has since been borne out in practice.

"On the Numerical Simulation of Radiation Boundary Conditions by Damping," by Orszag and Israeli (1974) investigated one way to solve wave propagation problems in infinite geometries and its possible pitfalls. The techniques are applicable to the numerical simulation of the collapse of turbulent wakes in stratified fluids. A paper including these results and others is being prepared for publication.

A review paper "Numerical Simulation of Viscous Incompressible Flows," by Orszag and Israeli (1974), summarized the state of the art of numerical hydrodynamics in 1974. A number of new results were published in this report, including compact difference schemes, formulation of good techniques for imposition of rigid boundary conditions, properties of spectral methods, and Reynolds number independence of large scales of turbulent flows.

In "Local Errors of Difference Approximations to Hyperbolic Equations," Orszag and Jayne (1974) disproved the old argument that high-order difference and spectral methods are not as effective as low-order methods for problems with shocks and other discontinuities.

"Numerical Simulation of Turbulence," by Orszag (1975) gave an account of progress in the numerical simulation of turbulent flows, including homogeneous turbulence and turbulent shear flows.

In "Design of Large Hydrodynamics Codes," Orszag (1976) reviewed the design considerations of large hydrodynamics codes, concentrating on the two-dimensional turbulence code KILOBOX.

In "Turbulence and Transition: A Progress Report," Orszag (1976) reviewed recent work on the numerical simulation of turbulent and transition flows.

In a monograph, "Lectures on the Statistical Theory of Turbulence," Orszag (1977) reviewed the current state of the statistical theory of turbulence. Several innovative developments are reported in his report, including eddy-damped Markovian models, which are currently popular.

"Numerical Simulation of Turbulent Flows," by Orszag (1977) is a survey of spectral methods for the solution of fluid flow problems and their applications to the simulation of turbulent flow problems.

In "Numerical Solution of Problems in Unbounded Regions: Coordinate Transforms" Grosch and Orszag (1977) discussed mapping methods for the solution of problems in infinite geometries.

Advanced Mathematical Methods for Scientists and Engineers by Bender and Orszag (1978) is an advanced graduate text on the approximate solution of difference and differential equations.

UNPUBLISHED WORK

The following research work is being prepared for publication, but no reports have yet been written. Results have been presented at research meetings.

In "Numerical Computation of the Direct-Interaction Approximation for Turbulent Shear Flows" Orszag and Kells have developed new algorithms for the solution of the direct-interaction equations. The new methods have been applied to the solution of the DIA equations for Burgers' equation and for general anisotropic turbulence that is homogeneous in space. Extensions to more general turbulent shear flows have been studied.

Orszag, in "Inertial Ranges of Two-Dimensional Turbulence," has made a detailed study of the two-dimensional entrophy cascade inertial range. Comparisons have been made with the predictions of the direct-interaction and test-field models.

"Tests of one-point turbulence closures" by Orszag compares simulations of anisotropic, homogeneous turbulence with the predictions of one-point closure models to evaluate constants in these models. Some constants are relatively independent of large-scale structures in the flows (like Rotta's constant for return-to-isotropy in axisymmetric turbulence) while others are very dependent on large-scale flows (like some constants appearing in the Lumley-Khajeh-Nouri model).

In "Numerical Studies of Transition in Pipe and Circular Couette Flows," Deville and Orszag made a detailed study of the sequence of instabilities of these flows by using a high resolution, three-dimensional spectral code. The results of these nonlinear numerical experiments and new linear theory are being prepared for publication.

In "Numerical Studies of Stratified Flows Past Cylinders," Orszag, Deville, and Jayne have simulated the wake of stratified flow past a cylinder. Their code employs radiation boundary conditions and has been used to test techniques for stratified flow calculations that eliminate reflected internal waves. These studies should be of particular importance in the further development of underwater hydrodynamics codes.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NR 061-223	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Final Report for ONR Contract No. N00014-72-C-0355 "Numerical Turbulence"		5. TYPE OF REPORT & PERIOD COVERED Final, 7/1/74-6/30/75
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Steven A. Orszag		8. CONTRACT OR GRANT NUMBER(s) N00014-72-C-0355
9. PERFORMING ORGANIZATION NAME AND ADDRESS Flow Research Company, A Division of Flow Industries, Inc. P.O. Box 5040, Kent, WA 98166		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 061-223
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research 800 North Quincy Arlington, VA 22217		12. REPORT DATE July 1977
		13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Defense Contract Administration Services Naval Support Activity Building 5D Seattle, WA 98115		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribued per letter ONR:438:RDC:cem, 15 July 1975

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

turbulence
pseudospectral
numerical simulation
pipe flows
wake collapse
minicomputers
anisotropic turbulence

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This communication summarizes the work performed on ONR Contract No. N00014-72-C-0355, Task NR 061-223, "Numerical Turbulence." Significant results have been reported in the reports referenced in this paper.

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